

Chapter 5 Digital Signal Processing

5.1 Introduction to Digital Signal Processing



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Not only do we have analog signals -- signals that are real-or complex-valued functions of a continuous variable such as time or space we can define **digital** ones as well. Digital signals are **sequences**, functions defined only for the integers. We thus use the notation $s(n)$ to denote a discrete-time one-dimensional signal such as a digital music recording and $s(m, n)$ for a discrete-"time" two-dimensional signal like a photo taken with a digital camera. Sequences are fundamentally different than continuous-time signals. For example, continuity has no meaning for sequences.

Despite such fundamental differences, the theory underlying digital signal processing mirrors that for analog signals: Fourier transforms, linear filtering, and linear systems parallel what previous chapters described. These similarities make it easy to understand the definitions and why we need them, but the similarities should not be construed as "analog wannabes." We will discover that digital signal processing is **not** an approximation to analog processing. We must explicitly worry about the fidelity of converting analog signals into digital ones. The music stored on CDs, the speech sent over digital cellular telephones, and the video carried by digital television all evidence that analog signals can be accurately converted to digital ones and back again.

The key reason why digital signal processing systems have a technological advantage today is the **computer**: computations, like the Fourier transform, can be performed quickly enough to be calculated as the signal is produced¹, and programmability means that the signal processing system can be easily changed. This flexibility has obvious appeal, and has been widely accepted in the marketplace. Programmability means that we can perform signal processing operations impossible with analog systems (circuits). We will also discover that digital systems enjoy an **algorithmic** advantage that contributes to rapid processing speeds: Computations can be restructured in non-obvious ways to speed the processing. This flexibility comes at a price, a consequence of how computers work. How do computers perform signal processing?

1. Taking a systems viewpoint for the moment, a system that produces its output as rapidly as the input arises is said to be a real-time system. All analog systems operate in real time; digital ones that depend on a computer to perform system computations may or may not work in real time. Clearly, we need real-time signal processing systems. Only recently have computers become fast enough to meet real-time requirements while performing non-trivial signal processing.